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GEOLOGY OF THE MENDERES MASSIF AND THE LYCIAN NAPPES SOUTH OF DENİZLİ, WESTERN TAURIDES

Aral İ. OKAY*

ABSTRACT.—Mount Honaz region in the Western Taurides is made up of superimposed several tectonic units. In the west, monotonous green metashales called the Honaz shale occur at the base of the tectonic stack. Honaz shale is tectonically overlain by weakly metamorphosed, massif white limestone, thinly bedded cherty limestone and shale which covers the Mendercs massif. Menderes massif is in turn tectonically overlain by the Sandak complex of the Lycian nappes made up of Mesozoic dolomites and limestones and ophiolite mainly of harzburgite lies oven the Sandak complex. All these tectonic units form an eastward overturned major anticline called the Honaz anticline; a pelagic sedimentary sequence of Late Cretaceous—Middle/Late Eocene age, called the Göbecik Tepe complex, occurs tectonically beneath the overturned limb of the Honaz anticline. The Göbecik Tepe complex constitutes the relative autochthonous in the region of the Mount Honaz. Different tectonic units in the Mount Honaz region show effects of Late Cretaceous, Middle Eocene and Late Eocene/Oligocene tectonics. Obduction of the ophiolite over the Sandak complex probably occurred during the Late Cretaceous, while the age of thrusting of the Sandak complex over the Menderes massif is probably Middle Eocene. Emplacement of these tectonic units over the Göbecik Tepe complex and the formation of the Honaz anticline is of Late Eocene/Oligocene age.

INTRODUCTION

The stratigraphy of the Menderes massif and the Lycian nappes and their tectonic relationship in the region between the Bafa lake and Muğla (Fig. 1) are known fairly well through studies carried out during the last twenty years (Graciansky, 1968; Dürr, 1975; Çağlayan and others, 1980; Erakman and others, 1986; Konak and others,1987). In contrast, farther northeast in the Kale-Tavas region little is known on the eastward extension of the Menderes massif and its relation to the allochthonous units. An area where these regional problems can be solved is the mountainous terrain south of Denizli which lacks the post-tectonic Tertiary cover. The Mount Honaz and the neighbouring areas south of Denizli are mapped on a scale of 1:25,000 with the aim of solving the internal structure and relation of the Menderes massif and the allochthonous units (Okay, 1986). This paper describes the geology of the region and summarizes the important results.

A geological definition of the Menderes massif is necessary in order to map its extent and its relation to other units. In this definition the region between the Bafa lake and Muğla, where the geology of the Menderes massif is best known, should be taken as a reference area (Fig. 1). The main features which characterize the Menderes massif in this region are (Graciansky, 1966; Başarır, 1970; Dürr, 1975; Alkanoğlu, 1978; Çağlayan and others, 1980; Okay, 1985; Konak and others, 1987) : (1) The Menderes massif is made up from the base upwards of Precambrian gneisses; Lower Paleozoic micaschists; Permo-Carboniferous metaquartzite, black phyllite and dark recrystallized limestone; Mesozoic, thickly bedded, recrystallized neritic limestones with bauxite horizons; recrystallized pelagic limestone and flysch of Paleocene to Early Eocene in age; (2) The Lycian nappes overlie tectonically the Eocene flysch of the Menderes massif. The emplacement age of the Lycian nappes over the Menderes massif is regarded as Mid-Eocene; (3) A Barrovian-type regional metamorphism of Eocene age has affected the Menderes massif; the metamorphic grade shows a gradual decrease upwards in the sequence (Ashworth and Evirgen, 1984; Okay, 1985; Satır and Friedrichsen, 1986). This regional metamorphism was related to the emplacement of the Lycian nappes over the Menderes massif (Şengör and others, 1984), and has also affected the lower

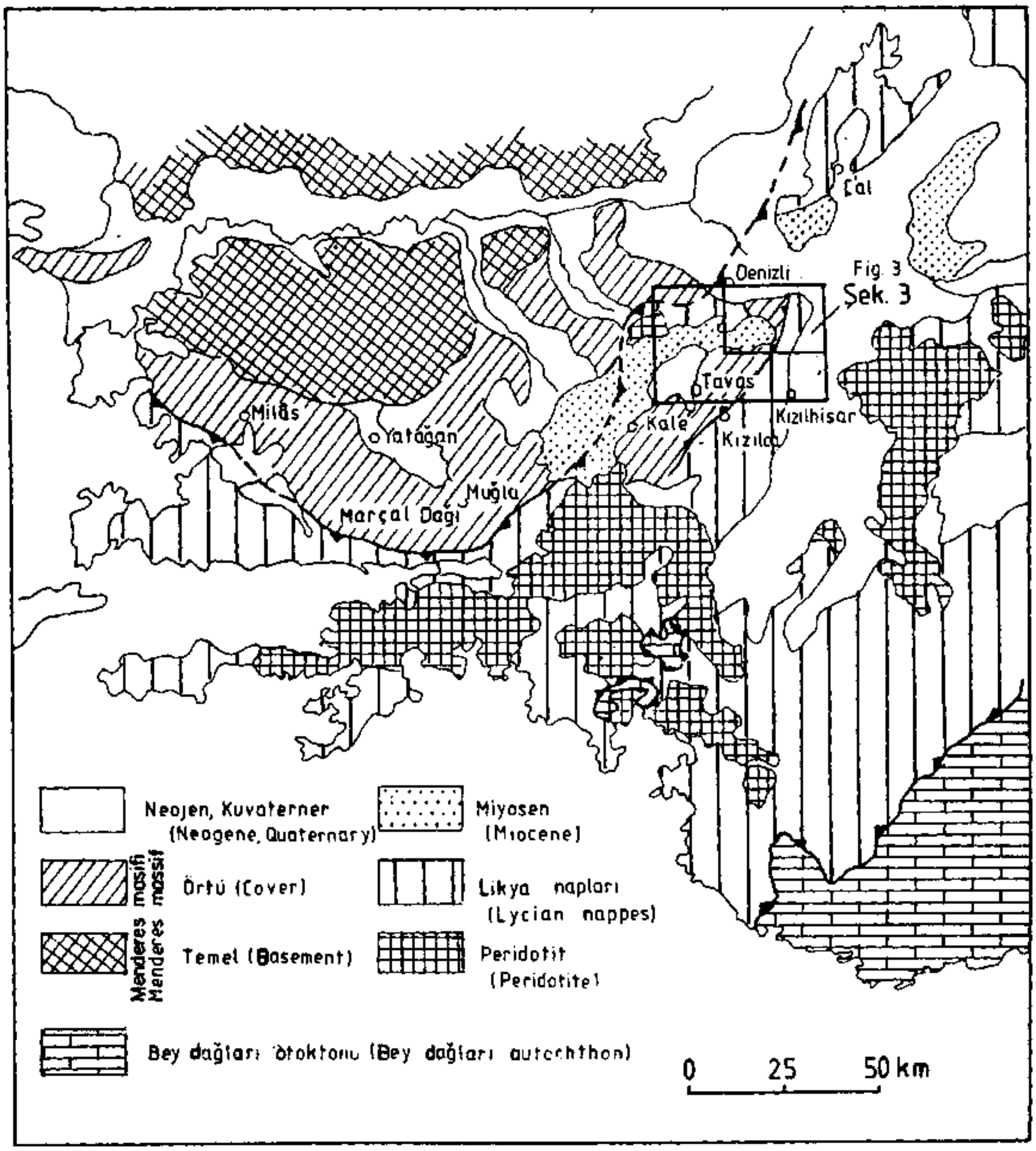

Fig.1 -- Simplified tectonic map of the Western Taurides showing the location of the studied area.

parts of the Lycian nappes, such that there is no metamorphic discontinuity between the Menderes massif and the overlying nappes. Apart from the Eocene mebamorphism, traces of an older Pan-African metamorphism have been documented in the Precambrian gneisses of the Menderes massif (Satır and Friedrichsen, 1986); (4) The Menderes massif forms the lowest tectonic unit in the region between the Bafa lake and Muğla and is the relative autochthon; (5) The Menderes massif has a relatively simple south and southeast dipping regional structure formed as a result of the regional uplift in the Oligocene. Large scale thrusts and isoclinal folds are not observed in the massif.

As can be deduced from the above features, the Menderes massif is a tectono-stratigraphic unit. The main features which characterize the Menderes massif are its stratigraphy, tectonic setting and regional metamorphism.

TECTONICFRAMEWORKOFTHEREGION

South of Denizli there are several major and secondary tectonic units forming a nappe stack. The relation between these tectonic units are shown schematically in Figure 2. At the top of the nappe stack is the Honaz ophiolite made up largely of ultramafic rocks, and restricted to the eastern part of the studied region. Sandak unit of the Lycian nappes lies tectonically below the Honaz ophiolite and above the Mesozoic-Early Tertiary cover sequence of the Menderes massif. The Menderes massif has an allochthonous position in the investigated area and is tectonically underlain by the Honaz shale made up of green phyllites which form the core of the Mount Honaz. In the east of the Mount Honaz this nappe stack is thrusc over the Göbecik Tepe unit made up of sedimentary rocks up to Mid/Late Eocene in age. The Zeytinyayla formation, which outcrops in the west can be correlated with the Göbecik tepe unit (Fig. 2).

main mass of the Menderes massif lie the Kale-Tavas Tertiary basin and allochthonous units of the Lycian nappes (Fig. 1 and 3). In the studied region the Mesozoic sequence of the Menderes massif tectonically overlies the Honaz shale, and is tectonically overlain by the Gereme formation of the Sandak unit. This relationship can be clearly observed in the Cemal damı locality (Fig. 3). The three uppermost formations of the Menderes massif which occur in the region are the Pınarlar formation, the Yılanlı formation and the Zeybekölen Tepeformation.

Pınarlar formation.— The Pınarlar formation outcrops around the Pınarlar village south of Tavas, and outside the area of Figure 3. It is made up mainly of slightly metamorphosed, pink, grey, bluish-grey, clean, medium to thickly bedded quartzite, fine to medium grained, red sandstone, red and green shale, yellowish-white dolomite, poorly sorted conglomerate with me-

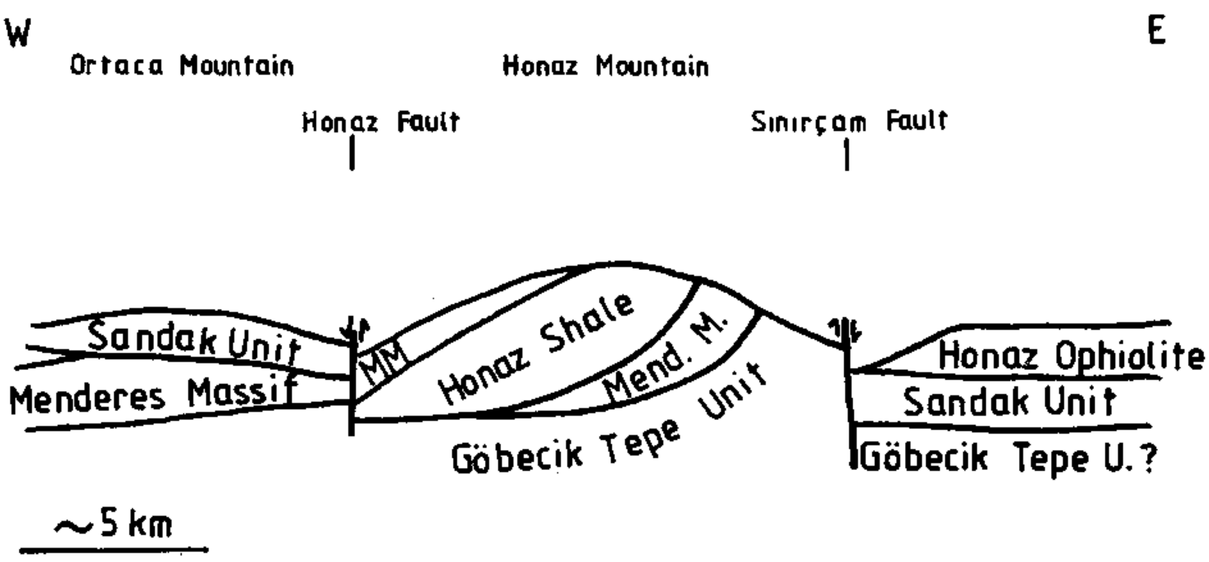

Fig.2— Schematized E–W section showing the relationship of the tectonic units in the studied region.

STRATIGRAPHY

The Menderes massif

Regionally metamorphosed sedimentary rocks outcropping over a large area extending from southeast of Tavas to the Mount Honaz are included into the Menderes massif sequence. Between these rocks and the

dium rounded, white and pink quartzite pebbles, and rare limestone lenses. The minimum apparent thickness of the Pınarlar formation is around 1000 meters. Quartzites with thicknesses of several hundred meters are the dominant lithology in the basal parts of the Pınarlar formation, abundant fusulinide forms were discovered in a dark grey limestone lens within the quartzites immediately east of the Pınarlar village, indicating a Late Permian age for the quartzites.

The Permo-Carboniferous sequence from the main mass of the Menderes massif is known for a long time from the regions of Göktepe, Karıncalıdağ and Babadağ (Phillipson, 1918; Onay, 1949; Kaaden and Metz, 1954; Schuiling, 1962; Dürr, 1975; Okay, 1985; Konak and others, 1987). This Permo-Carboniferous sequence is lithologically similar to the . Pınarlar formation, however, it includes abundant dark limestone and shale besides quartzite, and probably represents a slightly deeper marine environment during the Permo-Triassic.

Yılanlı formation.— A grey, light grey, thickly bedded-massif, locally laminated, fine-grained, locally gastropoda bearing apprx. 1500 m thick, monotonous carbonate sequence overlies the Pınarlar formation with a probable discordance (Neşat Konak, 1987, pers. communication). This limestone sequence, which represents the Mesozoic neritic carbonate cover of the Menderes massif, is named as the Yılanlı formation (Meşhur and Akpınar, 1984). It forms a major NE—SW striking mountain chain southeast of Tavas and extends to the slopes of the Mount Honaz (Fig. 1 and3). In the uppermost parts of this carbonate sequence west of the Kızılhisar rudist shell fragments are cautiously identified indicating that the age of the Yılanlı formation extends, as in other regions, up to the Late Cretaceous.

A typical feature of the Mesozoic neritic carbonate cover (Yılanlı formation) of the Menderes massif from the Bafa lake to Denizli is the presence of bauxite horizons within the carbonates. These bauxite horizons, which can be traced semi-continuously up to Denizli (Onay, 1949), are not found in the main mass of the Menderes massif southwest of Denizli and in the studied region, suggesting that the Mesozoic carbonate platform was deeper in this region and escaped the periodic subareal exposure inferred in regions farther southwest.

Zeybekölen Tepe formation.— An over 1000 m thick sequence of recrystallized pelagic limestone and shale occur above the Yılanlı formation. This sequence forming stratigraphically the highest part of the Menderes massif in the studied region, shows important lithological and thickness changes from the corresponding sequence in the main part of the Menderes massif, and was therefore assigned to a separate formation. The Zeybekölen Tepe formation is named after the Zeybekölen Tepe east of Tavas, and the reference section is the Sarp stream valley between Tavas and Büyükkale Viran hill (Okay, 1986). The Zeybekölen Tepe formation outcrops' extensively east of Tavas and in the slopes of the Mount Honaz (Fig. 3).

The Zeybekölen Tepe formation is made up of slightly metamorphosed, thinly to medium bedded, grey, light grey, red limestone with frequent chert nodules, calciturbidite, shalely limestone and friable, fine-grained, light green shale. In the Mount Honaz the Zeybekölen Tepe formation begins with thinly to medium bedded, grey pelagic limestone with 2-3 cm thick white chert bands overlying conformably the neritic limestones of the Yılanlı formation. These cherty limestones pass upwards to thinly bedded pink limestones, shalely limestone and shale. The Gereme formation of the Sandak unit overlies the shales with a nappe contact (Fig. 3).

In the main mass of the Menderes massif the pelagic limestone and flysch of Paleocene to Early Eocene age forms the equivalent of the Zeybekölen Tepe formation and can be traced from the Bafa lake to Denizli as a marker horizon defining the uppermost part of the Menderes massif. In the region between the Bafa lake and Milas the variegated pelagic limestones are called the Kızılağaç formation (Brinkmann, 1967) and the overlying flysch the Kazıklı formation (Dürr, 1975). The palaeontological age data on these formations all come from the Marçal mountains southeast of Milas where the effects of the regional metamorphism have been very slight (Gutnic and others, 1979; Konak and others, 1987). Tectonically the Kızılağaç formation represents the foundering of the Mesozoic carbonate platform of the Menderes massif in front of the advancing Lycian nappes, while the Kazıklı formation represents the overriding of the foundered carbonate platform by the Lycian nappes. Therefore, the ages of these formations will be strongly time-transgressive and related to their geographic positions with respect to the

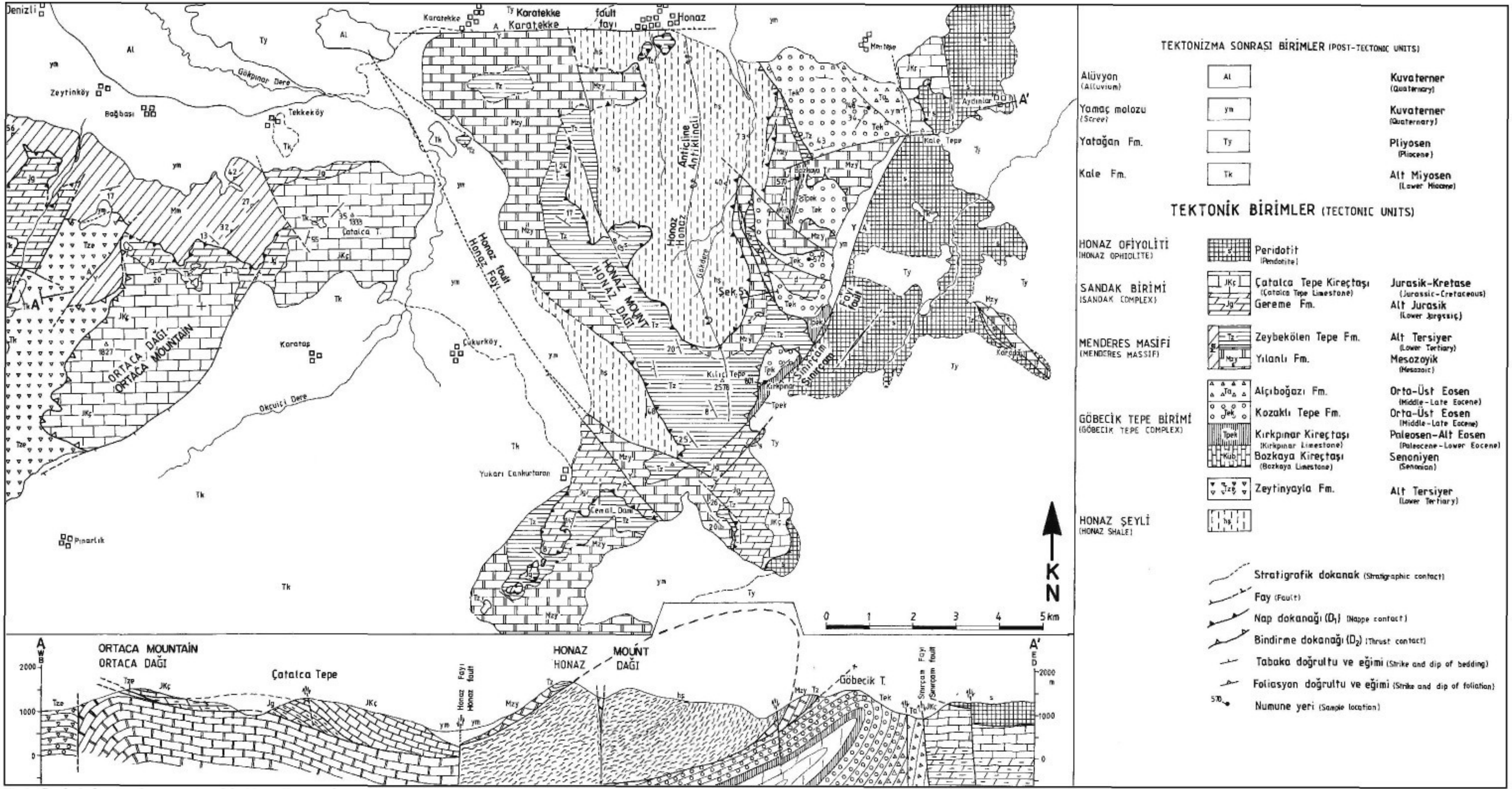

Fig 3 - Gerological map and cross-section of the Mount Honaz and surrounding area. For location see Fig 1 advancing Lycian nappes. However, the termination of the neritic carbonate cover of the Menderes massif with rudist-bearing limestones both in the region of Milas and Denizli indicates that in both of these regions the Lycian nappes were emplaced over the Menderes massif at a similar period. Therefore the age of the Zeybekölen tepe formation is provisionally taken as Paleocene-Early Eocene. The strong recrystallisation in the Zeybekölen tepe formation prevents any direct dating through fossils.

The allochthonous position of the sequence assigned to the Menderes massif in the studied area contrasts with the autocthonous position of the Menderes massif in the main mass. However, as described above this sequence is otherwise very similar, in terms of its stratigraphy, metamorphism and the overlying tectonic units,to that of the main mass of the Menderes massif. Its present allochthonous position is due to major post-metamorphic thrusting not observed in the main mass of the Menderes massif. For these reasons this sequence was assigned to the Menderes massif rather than to a new tectonic unit.

Sandak unit

Allochthonous units between the Menderes massif and the Bey Dağları authochthon are collectively known as the Lycian nappes. The Lycian nappes include various tectonic units ranging from continental margin deposits to ophiolites (Graciansky, 1972; Erakman and others, 1986). In the 250 km long region between the Bafa lake and Denizli a rootless tectonic unit of Mesozoic continental margin deposits overlies tectonically the Lower Eocene flysch of the Menderes massif. Recent studies have shown that this unit is in fact composite, and consists of two similar units called the Sandak and Haticeana units (Erakman and others, 1986). The main differences between these units are that the age of the Haticeana sequence ranges up to the Early Eocene, as in the Menderes massif, while the Sandak sequence is terminated at Late Cretaceous, and the post-Liassic rocks of the Haticeana unit are more pelagic than rocks of the corresponding age in the Sandak unit (Erakman and others, 1986). In the region between Muğla and Gölhisar, where these units are differentiated, the thrust stack consists from the base upwards: Menderes massif, Haticeana unit, Sandak unit, ophiolitic melange and ophiolite (Erakman and others, 1986). The unit tectonically overlying the Menderes massif south of Denizli is similar to the Sandak unit in terms of its stratigraphy and its tectonic position directly below the ophiolite, and was therefore assigned to this unit. In this region the Sandak unit consists of three formations: the Karaova formation, the Gereme formation and the Çatalca Tepe limestone.

Karaova formation.— The Karaova formation, which outcrops northwest of the Kızılcabölük outside the area of Figure 3, consists of slightly recrystallized, red, purple, bluish-grey shale, sandstone, conglomerate with quartz pebbles, quartzite and rare limestone horizons. It has a minimum thickness of 500 m and passes upwards gradually to the Gereme formation.

The Karaova formation has a striking appearance in the field with its multicoloured shales, and can be traced in its typical lithology from Bodrum to Uşak (Okay, 1985). The formation was first described and named by Phillipson (1918) from the Bodrum Peninsula. Its characteristic lithology in the Tauride Scythian lithofacies and the conformable overlying Late Triassic-Liassic Gereme formation indicate a Triassic age for the Karaova formation.

Gereme formation.— The Gereme formation is made up of monotonous, massively to thickly bedded, generally grey, dark grey dolomites; its maximum thickness is 500 meters; the cavernous surface wheathering is very characteristic for the dolomites of the Gereme formation. In the studied region the Karaova formation has acted as a decollement horizon during the thrusting so that the Gereme formation lies tectonically directly over the Menderes massif; the Gereme formation is overlain by the Çatalca Tepe limestone. These relationships can be clearly observed south of the Mount Honaz (Fig.3).

The Gereme formation can be traced with its characteristic dark dolomites within the Sandak and Haticeana units from the Bodrum peninsula to the region of Uşak. In fact, the Gereme formation was initially named by Blumenthal (1918) from the region of Milas, and is described in detail by Graciansky (1968) and Bernoulli and others (1974). In the studied region no fossils have been determined in the Gereme formation which consists completely of dolomites; its Late Triassic-Liassic age is based on fossils determined in undolomitised limestones from the region of Bodrum (Bernoulli and others, 1974); the same age range is cautiously accepted for the Gereme formation in the studied region.

Çatalca Tepe limestone.— Grey, dark grey, massive to thickly bedded limestone with rare small chert nodules which overlies the Gereme formation is named as the Çatalca Tepe limestone. The name of the formation derives from the Çatalca Tepe in the Ortaca mountain (Fig.3). The maximum thickness of the Çatalca tepe limestone is 750 meters. The Çatalca Tepe limestone is tectonically overlain by the Honaz ophiolite, which can be observed around the Kale tepe northeast of the Mount Honaz, and south of the Mount Honaz (Fig.3).

The Çatalca Tepe limestone is made up of slightly recrystallized micrite/dismicrite, sparsely packed biomicrite. Ostracoda, Milliolidae, Opthalmidiidae, Gastropoda, Brachiopoda, *Clodocoropsis* sp. have been determined in the collected specimens. Among these forms *Clodocoropsis* sp. indicates a Late Jurassic-Early Cretaceous age range. Based on this form, and the general stratigraphy of the Sandak unit (Erakman and others, 1986), the age range of the Çatalca Tepe limestone is taken as Dogger-Late Cretaceous.

An Upper Cretaceous flysch is generally present at the top of the Sandak unit (Erakman and others, 1986). This flysch, representing the emplacement of the ophiolite and ophiolitic melange over the Sandak unit, is not observed in the studied region probably because of tectonic omission, and the ophiolite sits directly on the Çatalca Tepe limestone.

Honaz ophiolite

The ophiolitic rocks outcropping extensively east of the Mount Honaz and consisting dominantly of serpentinised peridotite are called as the Honaz ophiolite. As can be clearly seen north of the Kale tepe (Fig.3), the Honaz ophiolite lies along a subhorizontal tectonic contact over the Çatalca Tepe limestone and constitutes the highest tectonic unit in the region. The Honaz ophiolite is cut by several subvertical faults; its contact with the Göbecik Tepe unit along the eastern margin of the Mount Honaz is also a major normal fault.

The major part (> 98%) of the Honaz ophiolite is made up of dark green, blocky, partially serpentinised and locally silicified harzburgite. Apart from the ultramafic rocks, there are also minor gabbro and chromite bodies.

Honaz shale

Slightly metamorphosed, dark bluish-green friable shale and siltstone sequence forming the core of the Mount Honaz is called as the Honaz shale. The Honaz shale has a very monotonous lithology and generally shows no bedding or a regular schistosity. It underlies tectonically the Yılanlı, and Zeybekölen Tepe formations of the Menderes massif (Fig.3). East of the Mount Honaz it is thrust along with the Menderes massif over the Eocene sediments of the Göbecik Tepe unit.

Apart from the ubiquitous dark green shales, the Honaz shale also includes reddish siltstone, sandstone and conglomerate with quartz pebbles intercalated with the green shales in the eastern side of the Gökdere. Cross-cutting the shales are rare thick (>10m) dark andesite dykes. No fossils have been found in the Honaz shale.

Göbecik Tepe unit

The Göbecik Tepe unit comprising Mesozoic-Lower Tertiary sedimentary rocks, is a newly discovered unit in the studied region. It tectonically underlies the Menderes massif or the Honaz shale along the eastem margin of the Mount Honaz (Fig.3). The Göbecik tepe unit has got an imbricated internal structure and its contact with the Honaz ophiolite in the east is faulted. The name of the unit derives from the Göbecik tepe south of the Menteşe village. Göbecik Tepe unit is divided into four formation (Fig.4); these are from the base upwards : the Bozkaya Tepe limestone, the Kırkpı-

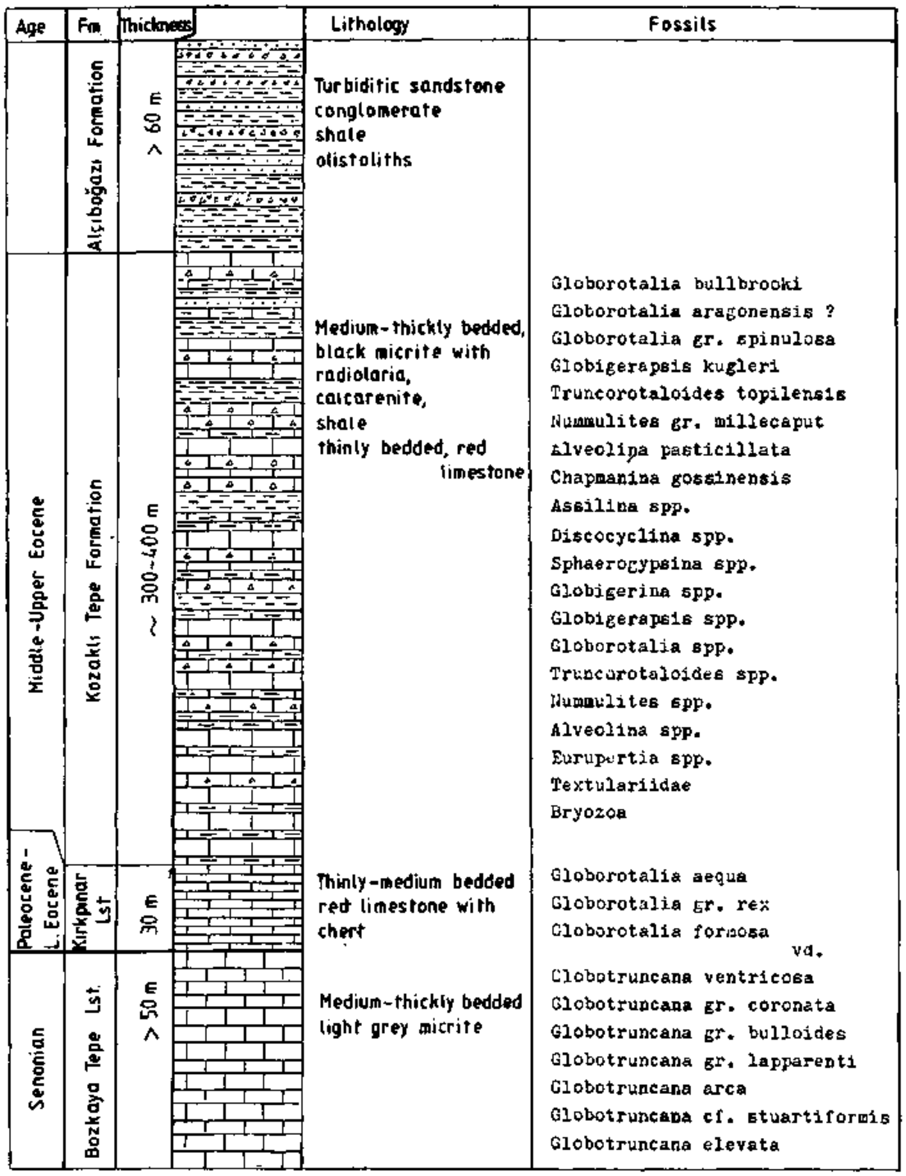

Fig.4— Stratigraphic section of the Göbecik tepe unit.

nar limestone, the Kozaklı Tepe formation and the Alçıboğazı formation.

Bozkaya Tepe limestone.—The Bozkaya Tepe limestone consists of medium to thickly bedded, cream coloured, microfossiliferous micritic limestone with infrequent chert lenses. It forms a ridge extending southward from the Bozkaya hill south of the town of Honaz. The reference and type sections are in the western side of the Bozkaya ridge. The Bozkaya tepe limestone has a minimum thickness of 80m; its lower contact with the Menderes massif is tectonic while it passes upwards conformably to the Kırkpınar limestone.

A specimen (570—A) collected from the middle part of the type section includes the microfossils of *Globotruncana ventricolosa, Globotruncana* gr. *coronata, Globotruncana* gr. *bulloides,* which indicate a Senonian (Campanian) age. Specimens collected higher up in the section include *Globotruncana elevata, Globot-*

runcana area, Globotruncana ventricosa, Globotruncana calcarata ?,forms characteristics for Late Campanian. The palaeontological data show that the Bozkaya Tepe limestone is of Late Senonian age. Subsequent studies have indicated that the age of the Bozkaya Tepe limestone may go down to Jurassic (Neşat Konak, 1987, personal communication).

Kırkpınar limestone.— The brick-red, thinly to medium bedded microfossiliferous micrite overlying the Bozkaya tepe limestone is called as the Kırkpınar limestone (Fig.4). The Kırkpınar limestone is overlain stratigraphically by the Kozaklı Tepe formation and tectonically by the Menderes massif. The thickness of the Kırkpınar limestone is 30 to 40 meters, the type and reference sections are along the Bozkaya ridge. The Kırkpınar limestone occurs, apart from the Bozkaya ridge, farther south in the Kırkpınar mevkii east of the Honaz summit. The name of the formation comes from this locality where its concordant stratigraphic contact with the overlying Kozaklı Tepe formation can be clearly observed.

The red, thinly bedded limestones of the Kırkpınar formation lie with a sharp but conformable contact on the grey limestones of the Bozkaya tepe limestone on the Bozkaya hill. A specimen (570—B) of the Kırkpınar limestone from this region contains *Globorotalia aequa, Globorotalia* gr. *rex, Globorotalia formosa, Globorotalia* gr. *laevigata, Globoratalia* gr. *convexa, Globigerina triloculinoides* indicating a Late Paleocene age. A specimen (801) collected from the uppermost part of the Kırkpınar limestone section in the Kırkpınar mevkii has the following microfossils *Globorotalia gracilis, Globorotalia rex, Globorotalia* gr. *mckannai ?, Globigerina* spp. of Late Paleocene ?-Early Eocene age. The palaeontological data and the age of the underlying Bozkaya tepe limestone indicates a Paleocene-Early Eocene age for the Kırkpınar limestone.

Kozaklı Tepe formation.— The Kozaklı Tepe formation consists of medium to thinly bedded, black micritic limestone with radiolaria, yellowish, thinly bedded sandy limestone, shalely limestone, red and green shale, calcarenite locally with abundant nummulites and thinly bedded red limestone. It lies conformably on the Kırkpınar limestone and is tectonically overlain by the Menderes massif (Fig.3). The name of the formation comes from the Kozaklı hill north of the Honaz summit. The reference section is the Kozaklı Tepe ridge. The thickness of the Kozaklı Tepe formation is 300-400 meters.

The Kozaklı Tepe formation constitutes the thickest and most widespread formation of the Göbecik tepe unit, and occurs along the eastern margin of the Mount Honaz. Its lower contact with the Kırkpınar limestone can be observed in the Kırkpınar mevkii where the thinly bedded red limestones of the Kırkpınar limestone are conformably overlain by the grey to black limestone-shale intercalation of the Kozaklı Tepe formation.

The major part of the Kozaklı Tepe formation consists of an intercalation of medium to thickly bedded, black, dark grey micritic limestone and yellowish grey shalely limestone. Within this sequence there are rare thinly bedded purple, red limestone, calcarenite locally with abundant nummulites and especially in the higher levels red and green shales. Calcarenites locally approaching bioclastic limestone contain apart from the nummulites reaching up to 2cm in length, quartz, green chert, chlorite-schist, shale and limestone fragments.

A specimen (748—A) from the red limestones from the Kozaklı Tepe formation contains *Globigerapsis kugleri, Truncorotaloides topilensis, Globorotalia bullbrooki, Globorotalia aragonensis ?* and indicate a Middle Eocene age. Several specimens collected from the nummulite-bearing calcarenites contain transoorted microfossils of Middle-Upper Eocene age. For example, a specimen (577) from the Kozaklı Tepe has *Discocyclina* spp., *Alveolina pasticillata, Nummulites millpcaput, Assilina* spp., and *Sphaerogypsina* spp., which indicate a Middle-Late Eocene or younger age. Interestingly the same specimen also contains transported Late Cretaceous microfossils, *Globotruncana* gr. *lapparenti, Gümbelina* spp. The palaeontological data indicate a Middle-Late Eocene age for the Kozaklı Tepe formation.

Alçıboğazı formation.— The Alçıboğazı formation consists of shale, sandstone, coarse sandstone and conglomerate with quartz, chert, serpentinite, limestone and volcanic rock fragments, and locally shows a wild-flysch character. The Alçıboğazı formation occurs southeast of the town of Honaz in the Alçıboğazı mevkii where it shows faulted contacts with the Kozaklı tepe formation. However, the lithological features of the Alçıboğazı formation suggest that it should overlie stratlgraphically the Kozaklı Tepe formation and thus should constitute the uppermost formation of the G6-becik tepe unit. Especially the upper parts of the Alçıboğazı formation have the features of an olistostrome; poorly sorted blocks of limestone, marblp, shale, red radiolarian chert reaching up to a few meters in size lie in a matrix of dirty green siltstone and sandstone. The minimum thickness of the Alçıboğazı formation is 60 meters.

No fossils have been found in the Alçıboğazı formation. However, its lithology indicates continuation of the rapid flysch deposition, which has already started in the Kozaklı Tepe formation, thus suggesting an Eocene age for the Alçıboğazı formation.

The Göbecik Tepe unit can be correlated in terms of its stratigraphy and tectonic setting with the Kızılca sequence described by Poisson (1977). The Kızılca sequence consists of Liassic to Middle Eocene sedimentary rocks with the post-Liassic sediments in pelagic facies. The Kızılca sequence which occurs in a small area south of Tavas has an imbricated internal structure and lies tectonically beneath the Mesozoic cover rocks of the Menderes massif.

Zeytinyayla formation

The flysch sequence locally with large limestone and sprpentinite blocks outcropping west of the Ortaca mountain is called the Zeytinyayla formation. The name of the formation comes from the Zeytinyayla mevkii northwest of the Ortaca mountain. The Zeytinyayla formation has an intermediate tectonic position between the Menderes massif below and the Sandak unit above (Fig.3).

The major part of the Zeytinyayla formation consists of slightly sheared preen, brown shale, siltstone sandstone and rare red shale. Within this clastic sequence there are occasional horizons of basic volcanic rock, calciturbidite and limestone, marble, radiolarite and serpentinite olistoliths up to 500 m in size. A limestone block (917—B) from the Zeytinyayla mevkii contains *Globotruncana area, Globotruncana* gr. *lapparenti, Globotruncana stuartiformis* of Campanian-Early Maastrichtian age. Thus, the depositional age of the Göbecik tepe formation is post-Maastrichtian.

The relation of the Zeytinyayla formation to the other tectonic units in the region is not well known. In terms of its lithology and the absence of regional metamorphism the Zeytinyayla formation is similar to the Göbecik Tepe unit and especially to the Alçıboğazı formation. However, it differs from this unit through its tectonic position above the Menderes massif. Nevertheless, the Zeytinyayla formation is here correlated with the Göbecik Tepe unit with its tectonic position above the Menderes massif attributed to a later thrusting event. However, it is equally possible that the Zeytinyayla formation constitutes the top part of the Sandak unit.

Neogene units

Neogene rocks overlie unconformably all the tectonic units in the studied region and are grouped into two lithostratigraphic units : the Kale (Meşhur and Akpınar, 1984) and the Yatağan (Becker-Platen, 1970) formations.

Kale formation.— In the studied region the major part of the Kale formation is made up of reddish green conglomerate with well rounded, polished serpentinite pebbles in a sandy and silty matrix Intercalated with the conglomerate are brownish green sandstone, siltstonp. shale and thin discontinuous coal beds. The Kale formation has a thickness of above 800 m and represents post-tectonic molasse facies deposits. It is overlain unconformably by the Yatağan formation.

Macrofossils collected by Becker-Platen (1970) 4 km south of Çukurköy (Fig.3) have given a Rupelian-Helvetian (Early Oligocene-Middle Miocene) age range. A more precise age range for the Kale formation comes from east of the town Kale outside the studied area; palaeontological data from this region indicate an Aquitanian age (Becker-Platen, 1970, Gökçen, 1978). In the Kale region the Kale formation is overlain through an angular unconformity by the Burdigalian marine limestones (Nebert, 1961, Becker-Platen, 1970, Gökçen, 1978). Thus, the data suggest that the Kale formation in the studied area is of Aquitanian age.

Yatağan formation.— The Yatağan formation, which outcrops east and north of the Mount Honaz (Fig.3) consists of white porous, hard, lacustrine limestone, grey, greyish green limely siltstone, sandstone, mudstone, basalt and coal. Yatağan formation has been assigned a Pliocene age by Becker-Platen (1970) based on molluscs, ostracoda and palinological determinations.

STRUCTURE

The studied region is a typical thrust/nappe belt. The structures in the region can be classified into three types based on their features and times of formation.

Nappes (D_1)

The first structures observed in the region is the stacking of the tectonic units as nappes. At the base of the nappe stack lies the Honaz shale. Honaz shale is tectonically overlain by the Mesozoic cover units of the Menderes massif. Farther up in the nappe stack lies the Sandak unit (Fig.2). The Sandak unit is thrust over by the Honaz ophiolite, which forms the highest unit in the nappe stack. In areas not directly affected by the later movements, the nappe contacts between these tectonic units are subhorizontal.

There are no data on the age of emplacement of the Honaz ophiolite over the Sandak unit. However, it is known that in the Taurides the ophiolite obduction over the carbonate platforms occurred during the Late Cretaceous (Özgül, 1976). Likewise, the age of the Sandak unit farther south is documented to range up to the Late Cretaceous (Erakman and others, 1986). Therefore, the emplacement of the Honaz ophiolite over the Sandak unit in the studied region is thought to have occurred during the Late Cretaceous.

The thrusting of the Sandak unit over the Menderes massif probably occurred during the Mid-Eocene. This emplacement age is based on the stratigraphy of the Menderes massif in the Margal mountains where it is shown to extend up to the Early Eocene (Gutnic and others, 1979; Konak and others, 1987).

The thrusting of the Menderes massif over the Honaz shale has occurred before the D1 movements; the D_2 structures of Late Eocene-Oligocene age truncate the tectonic contacts between the Honaz shale and the Menderes massif (Fig.3).

Thrusts and overturned isoclinal folds (D_2)

Following the emplacement of the nappes into the region, NNE—SSW striking and westward dipping thrusts and eastward overturned close-isoclinal folds developed as a result of NW-SE directed compression. The thrusts developed penecontemporenously with the overturned isoclinal folds, and frequently the isoclinal folds were transported over their overturned and sheared limbs. The D_2 structures have affected the D_1 nappe contacts and resulted in their folding and truncation; for example the D_1 nappe contact between the Honaz shale and the Menderes massif is folded and locally truncated by the D_2 structures (Fig.3).

The important D_2 structures shown on Figure 3 are the Honaz anticline and the Honaz thrust. These structures extend southward towards Tavas as a major SW—NE striking anticline with an axial length of over 20 km (Tavas anticline) and as a major thrust (Tavas thrust; Fig. 1, Okay, 1986).

Honaz anticline and Honaz thrust.— The Honaz anticline is a N—S striking, eastward overturned close anticline with an axial length of about 10 km (Fig. 2 and 3). Honaz anticline is sheared off along its overturned limb and is thrust over the Göbecik Tepe unit along the Honaz thrust. The nappe contact between the Honaz shale and the Menderes massif is folded during the D_2 phase and acquired the silhouette of the Honaz anticline (Fig. 3). Honaz shale occurs in the core of the Honaz anticline while the Mesozoic cover units of the Menderes massif occur in its flanks.

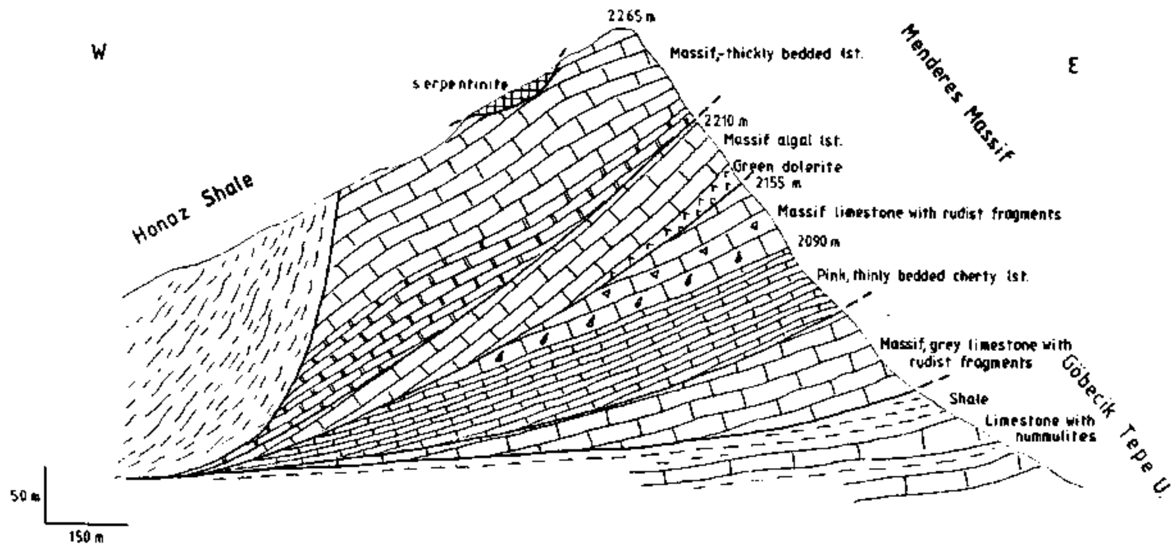

Fig.5 — Imbricated tectonic slices of the Mesozoic cover units of the Menderes massif along the Honaz thrust, Baymanlı ridge, the eastern side of the Mount Honaz. For location see Fig.3.

In some areas the Honaz thrust is not represented by a single thrust plane but by several closely spaced subparallel thrusts; for example in the eastern side of the Baymanlı ridge, the upper parts of the Menderes massif sequence is repeated four times in a 300 m thick section (Fig . 1 and 5).

The age of the D_2 structures is post-Middle Eocene based on their trans-cutting relationships to the D_1 structures; the Aquitanian Kale formation in mollasse facies gives an upper age limit for the D_2 structures. Therefore the age of the D_2 structures are constrained to the Late Eocene- Oligocene time interval.

Normal faults (D_3)

Following the NW—SE directed compression, the region was affected by a tensional regime with the formation of WNW—ESE and NE—SW striking major normal faults. These faults with important vertical throws cut the rocks of the Kale formation suggesting a post-Aquitanian age for their latest movements; their relation to the Yatağan formation is not known. Some of these important faults in the studied region are the Honaz, Sınırçam and Karatekke faults which surround the Mount Honaz like the sides, of a triangle (Fig.3). The Honaz fault is a major tectonic line limiting the southward and westward extension of the Honaz shale; a minimum of 1000 m throw is estimated along the Honaz fault. The Sınırçam fault can be traced for 11 km along the eastern side of the Mount Honaz; it constitutes the western limit of the Honaz ophiolite.

METAMORPHISM

All the tectonic units in the region with the exception of the Göbecik Tepe unit and the Zeytinyayla formation, have been affected by a low-grade regional metamorphism. The regional metamorphism was syn-to post-nappe emplacement (D_1), so that no discontinuity in metamorphic grade is observed across the nappe contacts, such as that between the Sandak unit and the Menderes massif; the metemorphic grade shows a regular decrease upwards in the tectonic sequence. However, the metamorphic grade in the studied region does not exceed that of the greenschist facies; biotite and garnet do not occur even in the Honaz shale which lies at the base of the nappe stack. The regional metamorphism in the studied region is thought to be of Eocene age similar to that in the southern margin of the Menderes massif.

In the Western Taurides the regional metamorphism decreases gradually and eventually disappears with increasing distance from the Menderes massif. The studied region lies in the threshold of this metamorphism. East of the Mount Honaz no effects of the metamorphism is generally discemable while in the west an increasing degree of metamorphism is observed.

The absence of metamorphism in the Göbecik Tepe unit, which is believed to constitute palaeogeographically the eastward extension of the Menderes massif, may be due for two reasons: (a) the nappe cover over the Göbecik Tepe unit during the Eocene may have been thinner than that above the Menderes massif, or may have been non-existent, and/or (b) the heat flux during the Eocene may have been much higher in the region of the Menderes massif compared to the region of the Göbecik Tepe unit.

The Do structures in the studied region were post-metamorphic and resulted in the juxtaposition of the metamorphic and non-metamorphic units, for example the Menderes massif was thrust over the non-metamorphic Göbecik Tepe unit.

THE TECTONIC EVOLUTION OF THE REGION

The Taurides are characterized by sedimentation without important orogenic breaks from the Early Paleozoic to the Late Cretaceous. The orogenic movements started in the Late Cretaceous, and have continued with several phases up to the present. Within this framework the tectonic evolution of the region is shown in Figure 6 for different time periods and is explained briefly below.

Early Cretaceous (Fig. 6a)

The relative position of the tectonic units in the studied region are shown in Figure 6a for the Early Cretaceous when the orogenic movements have not started, and quiete carbonate sedimentation was continuing. The important features are the position of the Göbecik Tepe unit in a pelagic basin (Kızılca basin, Poisson,1984) south of the Menderes massif, and the position of the Sandak unit to the north of the Menderes massif. Farther north lay the Tethys ocean now represented by the ophiolites south of the Izmir-Ankara suture.

The Kızılca basin is a pelagic trough thought to have lain between the Menderes massif and the Bey Dağları autochthon (Poisson, 1984). This basin, bordered by two shallow carbonate platforms, was initiated during the Lias and preserved its basinal character till the Late Cretaceous; in this respect it can be correlated with the Ionian basin in Greece also lying between two carbonate platforms (Poisson, 1984).

Late Cretaceous (Fig. 6b)

During the Senonian the ophiolites were emplaced on the continental margin and platform sediments of the Taurides. The emplacement of the Honaz ophiolite over the Sandak unit is similarly thought to have occurred in the Late Cretaceous.The effects of this major obduction event were felt in the Anatolide-Tauride carbonate platform: the platform was initially uplifted by elastic rebound and partially eroded, then as the ophiolite nappe approached the platform foundered and became a transient pelagic basin (Fig. 6b). The ophiolite nappe did not reach the Menderes massif and the Göbecik Tepe unit, where the sedimentation continued up to the Eocene.

Middle Eocene (Fig. 6d)

Following the ophiolite emplacement during the Late Cretaceous, the orogenic movements started again in the Middle Eocene after a quiete period during the Palaeocene. During the Middle Eocene the carbonate platform was internally imbricated and the Sandak unit with its cover of the Honaz ophiolite was thrust over the Menderes massif. The Menderes massif became buried under the nappe cover and underwent a Harrovian-type regional metamorphism.

Late Eocene—Oligocene (Fig. 6e)

After the nappe emplacement and regional metamorphism, major eastward overturned megascopic folds and thrusts developed during the D_2 period due to NW—SE compression. The Mesozoic cover units of the Menderes massif became detached from their basement and were thrust over the Göbecik Tepe unit during these D_2 movements.

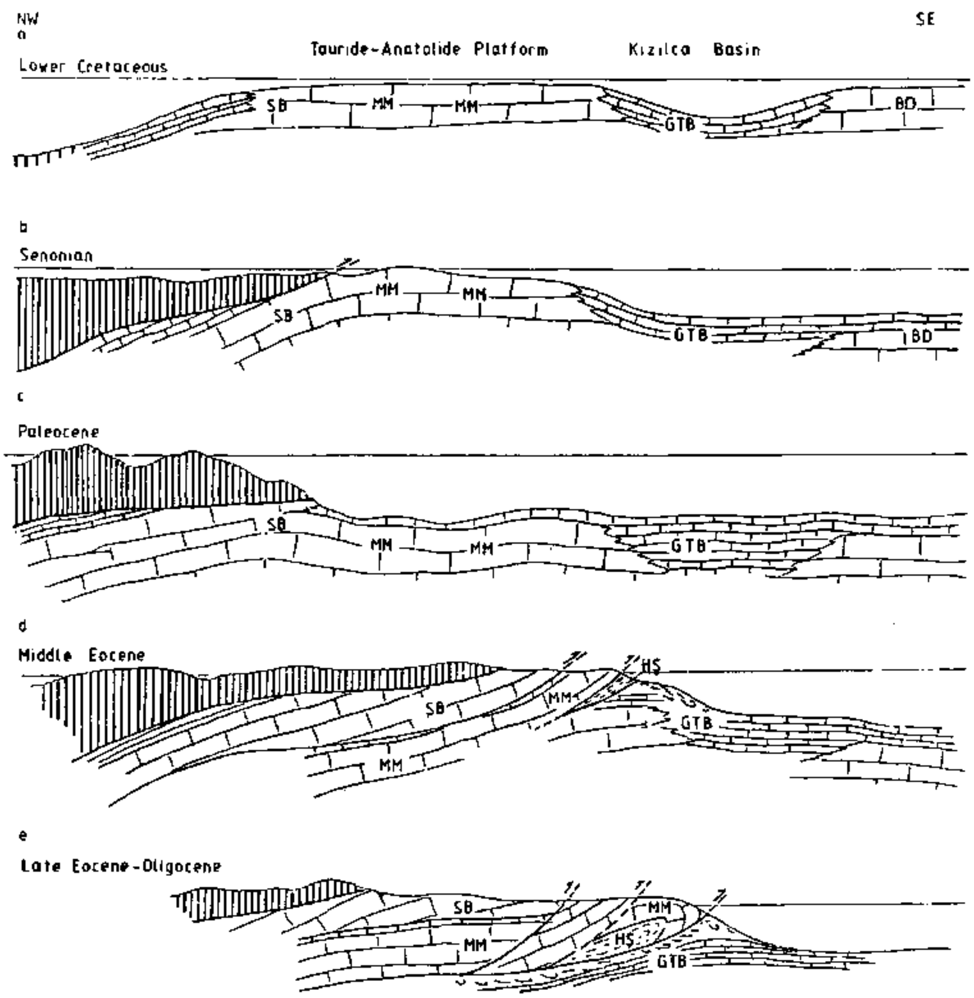

Fig.6– Schematized paleogeographic sections illustrating the tectonic evolution of the region.
SB– Sandak unit; MM– Menderes massif; GTB– Göbecik tepe unit; BD– Bey dağları autochthon; HS– Honaz shale.

Late Miocene—Pliocene

Fluvial sediments of the Kale formation were deposited over the whole area during the Aquitanian. Normal faulting following this sedimentation resulted in a block uplift of the Honaz and Ortaca mountains and subsequent erosion. This tectonic regime is still continuing today.

CONCLUSIONS

The important conclusions and results of this study are listed below :

Five major tectonic units are present in the region of the Mount Honaz. These are from the base upwards: Göbecik Tepe unit, Honaz shale, Menderes massif, Sandak unit and the Honaz ophiolite.

The Göbecik Tepe unit, which is first described in this study, comprises a Mesozoic-Tertiary sedimentary sequence ranging up to Middle/Upper Eocene in age, and constitutes the relative autochthon in the studied region.

The Menderes massif sequence represented by the Mesozoic cover rocks, has an allochthonous position and is thrust over the Honaz shale and the Göbecik Tepe unit.

The Mount Honaz has an eastward overturned anticlinal structure. The Honaz anticline is sheared along its overturned limb and is thrust eastward.

Three deformational phases are differentiated in the region: D_1, nappe emplacement and metamorphism during the Middle Eocene; D_2, eastward overturned folds and thrusts during the Late Eocene—Oligocene; D_3, post-Aquitanian normal faulting.

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